ANALYSIS OF THE VENUS SURFACE THERMAL EMISSION IMAGES TAKEN BY THE VMC CAMERA, VENUS EXPRESS.

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Introduction: This work is a continuation of the analysis of the night-time images of 1-μm thermal emission of Venus taken with VMC camera [1] onboard Venus Express. Our study area is SW of Beta Regio topographic rise, which includes parts of Hinemoa and Gunda Planitiae with Tuulikki Mons volcano and small Chimon-mana Tessera branching from the Phoebe Regio rise. Based on current knowledge of Venus geology we suggest that plains and Tuulikki Mons volcano are made of basaltic lavas, while the composition of material of Chimon-mana Tessera is enigmatic: it may be also basaltic or, as suggested by [2], more geochemically evolved (rhyolite, dacite, andesite). The idea is to test possible compositional differences with IR emissivity (*e*) of the surface material. Short description of this area and method of the VMC data analyis can be found in [3]. Here we present results of our analysis.

Table 1.

Unit	Terrain	Altitude, km	*N*
1	Chimon-mana Tessera	0.6±0.8	103
2	Plains around Chimon-mana	0±0.6	395
3	Tuulikki top	0.78±0.8	22
4	Tuulikki middle	-0.2±0.5	63
5	Plains around Tuulikki	-0.38±0.5	162

Data analysis: We compare (Fig. 1) tessera (central part of Chimon-mana Tessera, unit 1) v.s. the surrounding regional plains (unit 2), and relatively young Tuulikki Mons volcano (unit 3) and its summit part (unit 4) v.s. the surrounding regional plains(unit 5). The unit altitudes are given in Table 1.

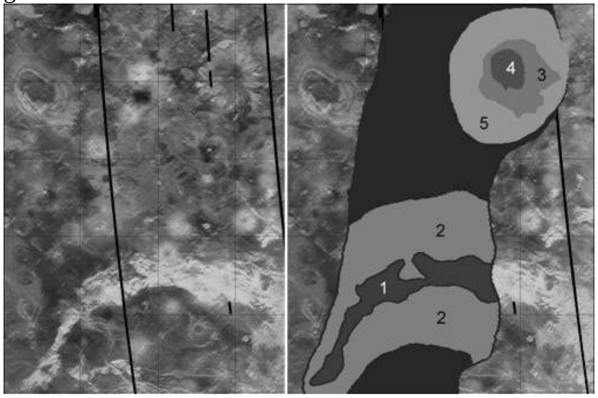

Fig. 1. Radar image of the study area with units (Tab. 1) marked

Calculation of 1-μm emissivity *e* from the observed thermal emission [3] requires two assumed model parameters: temperature lapse rate *r* and average surface emissivity $\bar{e}$. For each pixel we calculated *e* for 4 sets of the assumed parameters (Tab. 2), which are combinations of 2 values of the lapse rate *r* = -8 K/km and *r* = -5 K/km, and 2 values of the mean emissivity $\bar{e}$ = 0.8 and $\bar{e}$ = 0.58. The values *r* = -8 K/km and $\bar{e}$ = 0.8 have been used in a number of previous publications [e.g., 4], while *r* = -5 K/km and $\bar{e}$ = 0.58 have been used by [5].

The decrease of the assumed lapse rate leads to a hotter model temperature of the high-standing landforms and thus to their higher model 1-μm emission, which in turn leads to lower emissivity of the high-standing landforms calculated from the VMC data. The calculated emissivity of the plains for these two lapse rates should be rather similar. The decrease of the assumed average surface emissivity from 0.8 to 0.58 should "proportionally" lessen calculated emissivity of all terrains.

Table 2.

Assumed values	Unit A / Unit B	*e* ± std. dev.		*p*, %
		Unit A	Unit B	
r = -8 $\bar{e}$ = 0.80	1 / 2	0.78±0.29	0.69±0.24	0.8
	3 / 5	0.68±0.23	0.64±0.26	43
	4 / 5	0.80±0.24	0.64±0.26	0.6
r = -8 $\bar{e}$ = 0.58	1 / 2	0.56±0.20	0.51±0.18	2.2
	3 / 5	0.50±0.17	0.48±0.20	47
	4 / 5	0.58±0.17	0.48±0.20	2.4
r = -5 $\bar{e}$ = 0.80	1 / 2	0.61±0.22	0.64±0.24	23
	3 / 5	0.65±0.22	0.65±0.26	94
	4 / 5	0.63±0.18	0.65±0.26	72
r = -5 $\bar{e}$ = 0.58	1 / 2	0.46±0.17	0.48±0.17	34
	3 / 5	0.49±0.17	0.49±0.20	100
	4 / 5	0.48±0.20	0.49±0.20	83

We calculated the mean *e* and its standard deviation for each unit (Tab. 2). To assess significance of the observed differences in the mean *e* we applied Student's t-test for the unit pairs of interest. The atmosphere blurring makes our effective spatial resolution to be ~50 km, which is much larger than a formal field of view of the VMC pixel. So one cannot consider a value of each pixel as single and independent measurement. To correct this situation the study surface was "paved" with subareas of 50 km across. The number of such "tiles" on each unit (*N* in Tab. 1) was taken as the number of measurements for the t-test. The results of the estimates are given in Tab. 2; shaded are lines where the test indicates statistically significant emissivity difference.

It is seen from Tab. 2 that, as expected, the use of surface mean emissivity $\bar{e}$ = 0.58 has lead to the decrease of all calculated *e*. The use of *r* = -5 K/km leads to *e* of the high-standing Chimon-mana Tessera and Tuuliki Mons volcano to be lower comparing to calculations done for *r* = -8 K/km. So both cases with *r* = -5 K/km show no statistically significant difference between the compared units. The cases with r = -8 K/km do show significant differences between some terrains; we discuss this below.

Chimon-mana Tessera (unit 1) **v.s. adjacent plains** (unit 2)**.** For both cases with r = -8 K/km the calculated tessera emissivity is *higher* than the plains emissivity and the difference is statistically significant, contrary to [7], where *lower* emisvity for another tessera has been reported. The higher emissivity of the tessera material at first glance looks strange, because the indirect evidence [2] suggests less mafic (more silicic) composition of tessera comparing to more mafic material (basalt) of plains. So, one would expect the lower emissivity of tessera material comparing to that of plains that is opposite to our calculation results.

But this would be true if one considers the unweathered materials of tessera and plains. If these materials are weathered, then, calcium of the unweathered rocks (present in anorthite component of plagioclases and diopside component of pyroxenes) in the process of weathering should form forms anhydrite [6] and this high reflectivity/low emissivity mineral (http://speclib.jpl.nasa.gov) should be more abundant on the surface of weathered basalts comparing to the surface of weathered rhyolites, dacites, andesites. So if the surface materials of tessera and plains are weathered (see e.g., [8]) the calculated higher emissivity of tessera comparing to plains is in agreement with suggestion that tessera material is more silicic than the surrounding basaltic plains.

However, this is not the only option. The 1- μm emissivity depends strongly on the grain size [see e.g., 3]. The tessera surface is higher by ~ 0.6 km than the surface of plains (see Table 1). On Venus at higher altitudes wind should be stronger than at the lower ones [9] and this may control the surface grains size: the higher the surface, the stronger the wind, and, probably, the coarser the surface material grain size. Thus, the observed higher emissivity of tessera comparing to plains could be in agreement with the higher (comparing to the plains) altitude of tessera even if the tessera mineralogy is the same as that of the plains. We also should have in mind the mentioned by [3] possibility that higher emissivity at higher altitudes may be artifact of our still imperfect model.

Tuulikki Mons volcano (unit 3) **v.s. surrounding plains** (unit 5)**.** Tuuliki is relatively gentle-sloping volcano with long lava flows that suggests its basaltic composition and most part of it is only slightly higher than the adjacent plains. So it is naturally to expect that the Tuulikki emissivity should be close to that of the surrounding plains. Our calculations for the cases with r = -8 K/km showed the calculated emissivities of Tuulikki volcano and adjacent plains are not statistically different.

Tuulikki Mons summit (unit 4) **v.s. surrounding plains** (unit 5)**.** Our calculations for r = -8 K/km show that the Tuulikki summit emissivity is higher than that of the plains surrounding the volcano and the difference is statistically significant. The Tuulikki morphology suggests the basaltic composition of the volcano, so mineralogy of its summit, should be rather similar to that of the surrounding plains and seems to be not the cause of the observed higher emissivity of the Tuulikki summit. The higher e of the latter can be due to the coarser character of the surface material of its summit expected due the stronger winds on the higher altitudes. The mentioned possibility of an artifact of our still imperfect model also should be kept in mind.

Additional evidence on the nature of the observed higher emissivities at the higher altitudes may be deduced from the e v.s. altitude correlation diagram (Fig. 2).

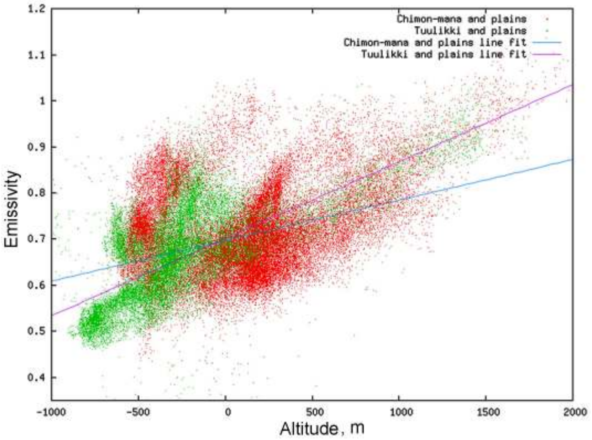

Fig. 2. The emissivity v.s. altitude correlation diagram.

It is seen from Fig. 2 that the measurement values for the area including Chimon-mana and the adjacent plains (green in Fig. 2) and the area including the Tuulikki summit and the plains surrounding this volcano (red in Fig. 2) form two different clusters with different trends. We suggest that this may imply that the physical mechanisms for the increase of emissivity with the altitude increase for these two areas may be different: the coarser grain size on the Tuulikki summeit and the combined effect of the coarser grain size plus difference in mineralogy for the Chimon-mana Tessera.

We should not forget also that for the temperature lapse rate r = -5 K/km, our calculation show no significant difference in surface emissivity for all considered unit pairs. It is still possible that the tessera is also basaltic and that there is no change in surface grain size with altitude change. So it is crucially important to reliably determine the temperature lapse rate in the near surface layer of Venusian atmosphere.

References: [1] Markiewizc W. et al. (2006) *Bull. Am. Astron.Soc. 38*, 511. [2] Nikolaeva O. et al. (1992) in *Venus Geology, Geochemistry and Geophysics*, 129. [3] Basilevsky et al., LPSC-41, abs. 1133. [4] Sief et al. (1985) *Adv. Space Res. 5* (11), 3. [5] Smrekar et al. (2010) Science, 328, 605. [6] Zolotov, M. Yu. (2007), in *Treatise on Geophysics*, G. Schubert (ed), 10, 349-370, Oxford: Elsevier Ltd. [7] Mueller N. et al. (2008) *JGR 113*, E00B17. [8] Pieters C. et al. (1986) *Science*, *234*, (4782), 1379-1383. [9] Kerzhanovich, V. & Marov, M. (1983) in *Venus*, D. M. Hunten, et al. eds, Univ. of Arizona Press, Tucson, 766-778.